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(71) Applicant (*for all designated States except US*): **UNIVERSITY OF SURREY** [GB/GB]; Guildford, Surrey GU2 7XH (GB).

(72) Inventors; and
(75) Inventors/Applicants (*for US only*): **TAFAZOLLI, Rahim** [GB/GB]; 184 Mulgrave Road, Cheam, Surrey SM2 6JT (GB). **SFIKAS, Georgios** [GR/GR]; 63 Nikomidias Street, Keratsini, GR-187 55 Pireas (GR).

(74) Agent: **MATHISEN, MACARA & CO.**; The Coach House, 6-8 Swakeleys Road, Ickenham, Uxbridge UB10 8BZ (GB).

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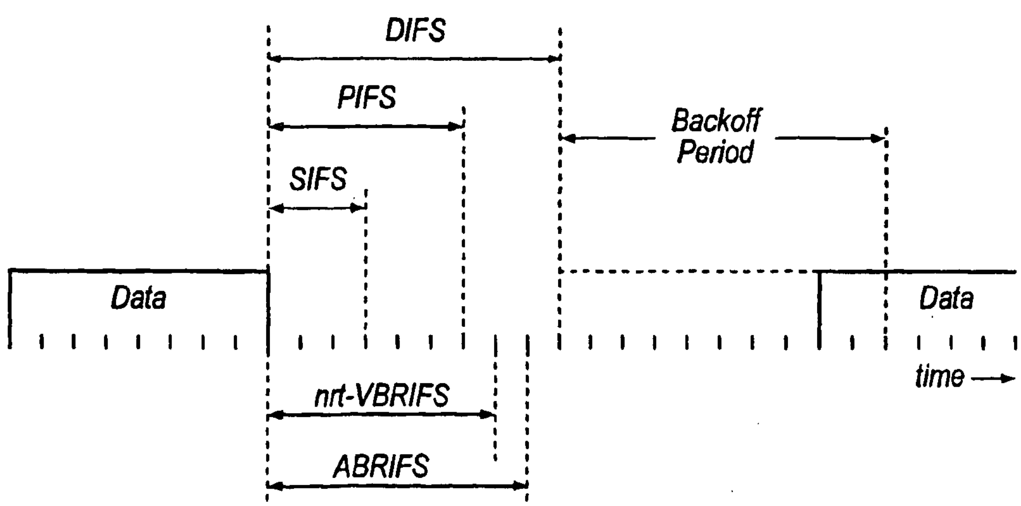
(54) Title: MEDIA ACCESS CONTROL FOR WIRELESS SYSTEMS



(57) Abstract: An asynchronous transfer mode (ATM) transmission method employs a MAC protocol including a Distributed Coordination Function (DCF) having a Distributed Interframe Spacing (DIFS) and a Point Coordination Function (PCF) having a Point Interframe Spacing (PIFS). The protocol has at least one additional IFS having an interval intermediate the interval of the DIFS and the interval of the PIFS.

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MEDIA ACCESS CONTROL FOR WIRELESS SYSTEMS

The invention relates to media access control (MAC) for wireless systems, particularly wireless Carrier Sense Multiple Access systems

The invention has particular, though not exclusive, applicability to the Media Access Control (MAC) protocol, known as Distributed Foundation Wireless MAC (DFWMAC) drawn up by the IEEE 802.11 Committee, tasked with the role of standardising protocols for Wireless Local Area Networks (WLANs) - see IEEE, Draft Standard IEEE 802.11, Wireless LAN, P802.11/D1, December 1994.

DFWMAC is a hybrid multiple access protocol because the existence of an Access Point (AP) is not necessary for protocol operation. The protocol also enables an ad hoc network with distributed control to be established. It is also capable of supporting both asynchronous data services and delay sensitive applications by dividing transmission time into frames, each frame consisting of two parts - a 'controlled' part and a 'random' part. The physical layer uses Spread Spectrum (SS) access; both Frequency Hopping (FH) and Direct Sequence (DS) SS approaches have been adopted.

The MAC protocol uses a contention mechanism to allow stations to share a wireless channel. This mechanism is based on a Carrier Sense Multiple Access (CSMA)

mechanism, similar to the IEEE 802.3 standard. An extension of the CSMA to include a Collision Detection mechanism (CSMA-CD) is not possible in the radio environment, because a station cannot, simultaneously, transmit and receive on the same channel, as required in the part of the CSMA-CD protocol that detects for collisions (when two or more stations transmit at the same time). Therefore, a wireless terminal is not always able to determine that a collision has occurred until the end of the transmission period, making the detection of the collision very inefficient, since scarce resources are being wasted. However, the IEEE 802.11 MAC extends the CSMA protocol by introducing a Collision Avoidance mechanism (CSMA-CA), which reduces the collision probability. The basic protocol used in the CSMA-CA protocol is known as Distributed Coordination Function (DCF).

DCF is implemented in every station. It is used both for offering asynchronous data services, and as the basis for the development of a mechanism for offering 'delay bounded' service to delay sensitive applications. The CSMA-CA protocol is a variation of the usual CSMA protocol described in "Telecommunications Networks: protocol, modelling and analysis" by Mischa Schwartz, Addision Wesley series in Electrical and computer engineering, Addison-Wesley 1987. A node first listens to the channel to determine if the medium is available, and transmits only when the medium is idle. 'Collision avoidance' reduces the probability of a collision among contending terminals by calculating a random idle time at each terminal, during which the terminal defers transmission, waiting to see if the medium remains idle. A

graphical presentation of this mechanism, is shown in Figure 1(a).

A characteristic of the CSMA-CA protocol is the introduction of various values of InterFrame Spacing (IFS) to give priorities to different types of MAC packets. For the basic mechanism now described by way of illustration, only the Distributed IFS (DIFS) time is important. From the end of a frame transmission, the access procedure is the following:

- All stations do not transmit any information for a time period DIFS.

- The stations that have new packets to transmit (terminal A, say) calculate a random backoff number, which is a timer that indicates when this packet can be transferred (in time slots). However, the 'countdown' process starts after the expiration of the DIFS time (that is when the medium becomes idle). This random backoff time is given in Equation 1, where CW is the value of the contention window at the time of the calculation, and n a uniformly selected random number within [0,1].

$$(backoff\ time) = CWn \qquad (1)$$

In the illustrated example, the 'countdown process' for terminal A starts at the end of the DIFS interval (at time t_1) but stops (at time t_2) when the medium being accessed

becomes busy. The 'countdown process' recommences at the end of the next DIFS interval (at time t_3) for the remaining part of the backoff time (Δt), and terminal A will start to transmit (at time t_4) when the backoff time has expired, provided the medium remains idle.

The slot duration depends on the physical layer implementation. Its value is chosen in such a way that stations starting transmissions in different slots are guaranteed not to collide. The value of the CW in Equation 1 is initialised to CW^{min}. Retransmissions cause the value of CW to grow exponentially (binary exponential backoff) up to CW^{max}. In Figure 1a it can be seen that only one random backoff duration is being calculated for each packet. As explained, this duration is used as the starting value of a timer that only counts down when the medium is idle and stops when the medium is sensed busy. The packet is transmitted when the timer reaches zero. For the interest of fairness, a station cannot send packets that are separated only by a DIFS interval; it must calculate a backoff period, as described above, for each separate frame, resulting to a Single Station Throughput (SST), where 'packet time' is the length of the packet in time units (slots):

$$SST^{-1} = 1 + [DIFS + \tfrac{1}{2}CW^{min}]/(packet\ time) \qquad (2)$$

The basic CSMA-CA mechanism for the IEEE 802.11 MAC protocol has been further enhanced with:

(i) MAC level acknowledgements and retransmissions. The acknowledgements have priority over the rest of the packets, because the station that issues an acknowledgement (after the reception of a packet), uses the Short IFS (SIFS, as shown in Figure 1(a)) timer to decide that the medium is idle.

(ii) Special Ready To Send/Clear to Send (RTS/CTS) frames, which implements a mechanism for bandwidth reservation, reducing the hidden terminal problem in ad hoc WLANs. The CTS packet follows the RTS and has increased priority over the other packets, since it also uses the SIFS timer to decide on the state of the channel.

(iii) A contention free, access method, known as Point Coordination Function (PCF), through the use of the Point IFS (PIFS) timer, with a value between SIFS and DIFS (see Figure 1(a)). Terminals transmitting in the PCF have higher priority packets, because they decide that the channel is free faster than the terminals using the DIFS timer.

The point coordinator (one of the terminals in an ad hoc network, or an AP, if available) can take control of the frame transmission by using the PIFS to access the medium. Assuming the existence of an AP, the operation of the PCF is now explained: The AP informs each terminal of its turn to transmit, by polling it. The terminal transmits information, receives an acknowledgement and the AP polls the

next terminal in its polling list. Each of the mobile stations can appear more than once in the polling list, if necessary. The AP initiates the PCF periodically (every SuperFrame (SF) period). All the terminals in the coverage area of an AP being informed of the value of this period and the maximum duration of the PCF. At the end of the PCF period, the AP informs the mobile stations of the beginning of the next DCF period, by sending a certain packet. If the transmitted packets are being acknowledged by the receiving station, the acknowledgement transmission takes place when the SIFS timer expires (SIFS is shorter than PIFS). If a terminal does not react within a SIFS time interval, then the PCF (the AP) shall resume control and transmit the next frame after a PIFS gap.

The use of the above two access mechanisms (the PCF and the DCF) divides the SF period into contention free and contention parts, as shown in Figure 1(b). The lengths of each period are manageable objects. The contention free period is limited to allow coexistence between contention and contention free traffic. The maximum time that is allowed to be allocated to these services in a SF is such that at least one maximum size MAC Protocol Data Unit (PDU) can still be transmitted during the SF period. A phenomenon, known as SF stretching effect could take place, because a station may transmit a long MAC packet, that interferes with the start of the next SF period (as shown in Figure 1(c)). Since transmissions in the first, contention free, part have priority over transmissions in the second contention part, different kinds of traffic can be supported. Generally speaking, the first part (which uses the PCF) can be used for

delay sensitive services, such as voice and video, whereas the second part (which uses the DCF) can be used for delay independent services, such as general computer data transmissions.

The transmission rate of the IEEE 802.11 physical layer is either 1 or 2 Mbps, per Access Point (AP) (the physical layer overhead is always being transmitted at 1 Mbps). Several APs can be included in one location (i.e. a base station), resulting in a higher bit-rate, able to satisfy most of the ATM services requirements as described, for example, by Raif O. Onvural in Asynchronous Transfer Mode Networks: Performance Issues, Artech. House Inc 1994 ISBN - 0-89006-662-0. A simplified structure of the MAC frame, for data packets only, is shown in Figure 1(d). More details about the IEEE 802.11 MAC protocol, the different transmitted messages and the frame structure, can be found in the afore-mentioned IEEE, Draft Standard.

In general, random access protocols like CSMA-CA cannot adequately support delay sensitive applications. The delay in transmission encountered by a data packet depends on the offered load of the network. Random access techniques are suitable for multiplexing bursty sources and have the capability to keep the delay per packet low provided the aggregate traffic is a small portion of the system capacity. If this is the case for a WATM LAN, for example, then the DCF can be used and an adhoc network created amongst terminals. However, if the WATM LAN is required to operate more efficiently and offer high QoS to delay sensitive applications, even when

the offered load approaches system capacity, then the PCF approach would need to be used.

An objective of the present invention is to improve efficiency of operation and QoS, even when the offered load approaches system capacity. To that end, there is provided in the MAC protocol at least one additional IFS defining an interval intermediate that of the DIFS and the PIFS.

Accordingly, the present invention provides an Asynchronous Transfer Mode (ATM) transmission method for use in a wireless communications system, the method employing a protocol including a Distributed Coordination Function (DCF) having a Distributed Interframe Spacing (DIFS) and a Point Coordination Function (PCF) having a Point Interframe Spacing (PIFS), wherein said protocol includes at least one additional Interframe Spacing (IFS) defining an interval(s) intermediate the interval defined by said DIFS and the interval defined by said (PIFS).

In this way, the ATM QoS can be mapped to at least three different priorities, respectively defined by the PIFS (used for real time (delay sensitive) ATM services), the DIFS and the or each additional IFS (used for non-real time ATM services). This approach assumes, of course, that the associated primitives are appropriately modified to be compatible with the new protocol.

The or each additional IFS is capable of creating different priorities amongst different non-real time services such as nrt VBR (non-real time Variable Bit-Rate), ABR (Available Bit-Rate), UBR (Unspecified Bit-Rate) and UBR^+.

Embodiments of the invention are now described, by way of example only, with reference to the accompanying drawings: of which

Figure 1(a) illustrates a known CSMA-CA access mechanism,

Figure 1(b) illustrates a MAC protocol Superframe structure,

Figure 1(c) illustrates stretching effect of the Superframe structure of Figure 1(b),

Figure 1(d) illustrates a simplified packet structure according to the IEEE 802.111 MAC protocol and

Figure 2 shows a CSMA-CA access mechanism according to the invention.

At least one additional IFS is provided to create different priorities between non-real time ATM services that use the DCF or the contention part of the SF period.

Referring to Figure 2, a first additional IFS defining an interval ABRIFS supports

ABR traffic and serves to differentiate ABR traffic from UBR traffic (which is supported by the DIFS). Differentiation between ABR traffic and other types of ATM non-real time traffic (such as UBR traffic) is needed when two stations exchange RTS/CTS messages to reserve resources (band width) for, and transmit, those different types of traffic (for hidden node problem alleviation).

Provided that $\mathrm{PIFS} < \mathrm{ABRIFS} < \mathrm{DIFS}$ there will be no interference between the contention free and contention parts of the SF.

In another embodiment, also shown in Figure 2, a second additional IFS defining an interval nrt-VBRIFS is also provided. This additional IFS supports nrt-VBR traffic and serves to differentiate the nrt-VBR traffic from ABR traffic (which is supported by the ABRIFS) and from UBR traffic (which is supported by the DIFS).

The nrt-VBRIFS could be the same as the ABRIFS. In this case, even though the nrt-VBR and ABR services would have the same access priority (because their IFSs are the same) they could still be treated differently provided the ABR service is permitted to transmit larger MAC packets than the nrt-VBR service.

However, if the nrt-VBRIFS and ABRIFS have different values, then interference will be avoided if $\mathrm{PIFS} < \text{nrt-VBRIFS} < \mathrm{ABRIFS} < \mathrm{DIFS}$. Again, the afore-mentioned restrictions on packet size may apply to allow "fairness" in the use of the medium .

CLAIMS

1. An Asynchronous Transfer Mode (ATM) transmission method for use in a wireless communications system, the method employing a MAC protocol including a Distributed Coordination Function (DCF) having a Distributed Interframe Spacing (DIFS) and a Point Coordination Function (PCF) having a Point Interframe Spacing (PIFS), where said protocol includes at least one additional Interframe Spacing (IFS) defining an interval(s) intermediate the interval defined by said DIFS and the interval defined by said (PIFS).

2. An ATM method as claimed in claim 1 wherein said protocol includes a first said additional IFS defining a first interval and a second said additional IFS defining a second interval less than said first interval.

3. An ATM method as claimed in claim 2 wherein said at least one additional IFS is capable of establishing different priorities amongst non-real time ATM services.

4. An ATM method as claimed in claim 3 wherein said non-real time ATM services are transmitted during the contention period of a superframe (SF).

5. An ATM method as claimed in claim 3 or claim 4 wherein said first additional IFS is capable of distinguishing an ABR service from a UBR service and said second

additional IFS is capable of distinguishing nrt-VBR service from said ABR and UBR services.

6. A wireless communications system including means for carrying out the ATM method as claimed in any one of claims 1 to 5.

7. A protocol suitable for implementing the ATM method as claimed in any one of claims 1 to 6.

8. An ATM method substantially as hereindescribed with reference to the drawings.

9. A wireless communications system substantially as hereindescribed.

10. A protocol substantially as hereindescribed.

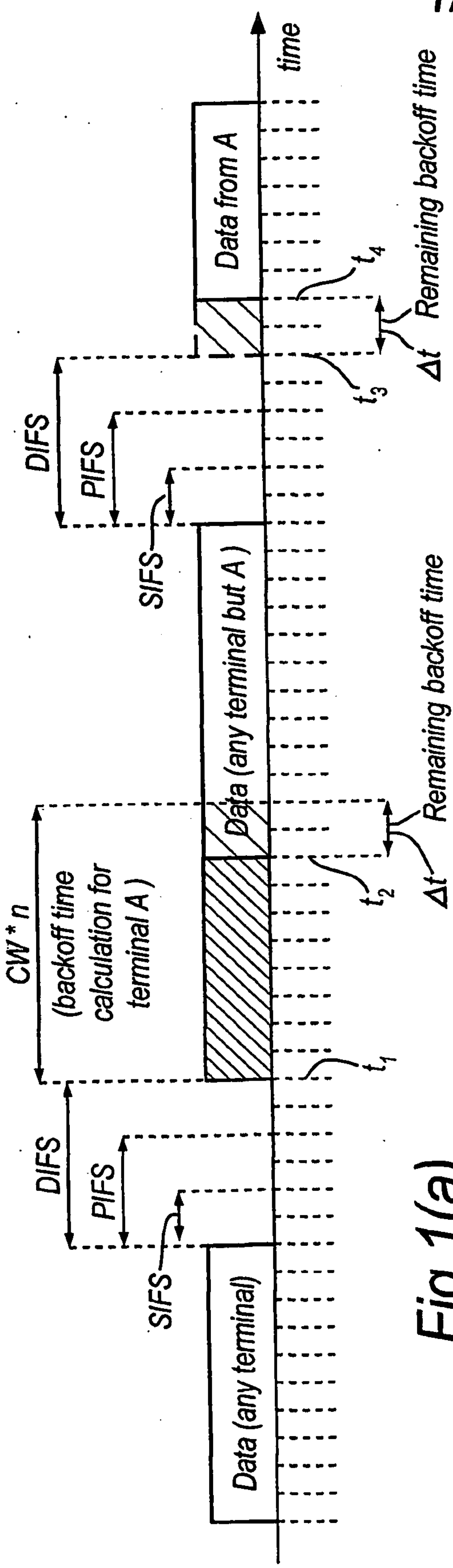
time
Data from A
Remaining backoff time
t_4
Δt
t_3
DIFS
PIFS
SIFS
Data (any terminal but A)
Remaining backoff time
t_2
Δt
CW * n
(backoff time calculation for terminal A)
t_1
DIFS
PIFS
SIFS
Data (any terminal)

Fig.1(a)

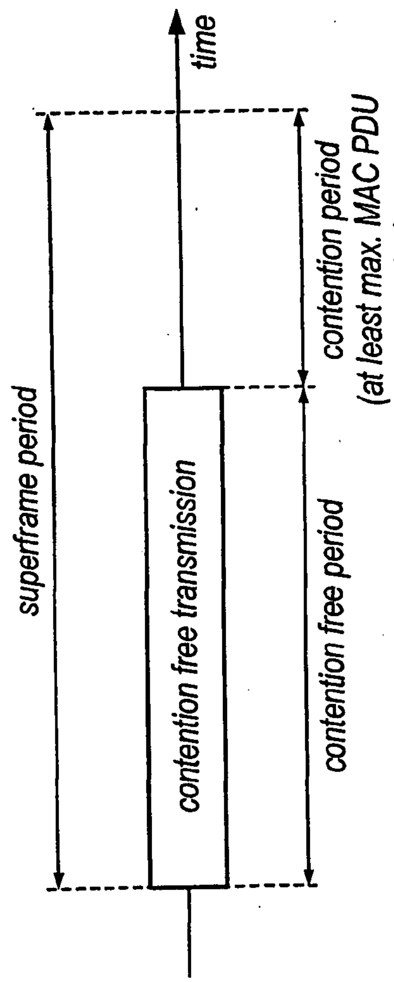
time
superframe period
contention period
(at least max. MAC PDU size)
contention free transmission
contention free period

Fig.1(b)

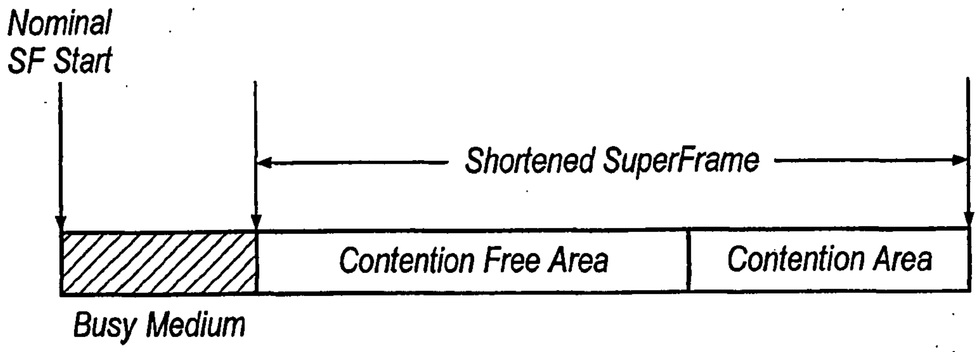

Fig.1(c)

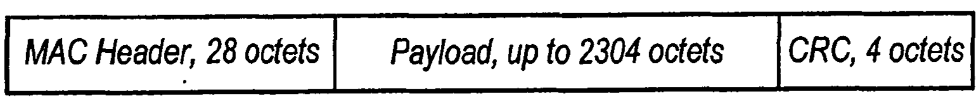

Fig.1(d)

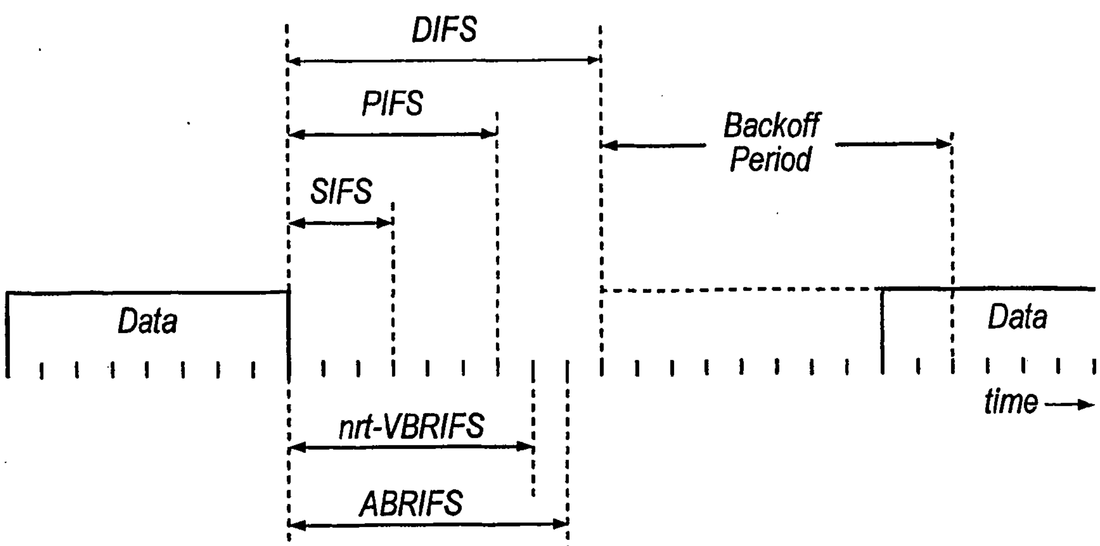

Fig.2

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 01/05032

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04L12/56 H04Q11/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CALLEGATI F ET AL: "Analysis of CSMA/CA protocol for wireless networking of ATM multiservice applications" GATEWAY TO THE TWENTY FIRST CENTURY. INTERNATIONAL CONFERENCE ON UNIVERSAL PERSONAL COMMUNICATIONS. 1996 5TH IEEE INTERNATIONAL CONFERENCE ON UNIVERSAL PERSONAL COMMUNICATIONS RECORD (CAT. NO.96TH8185), PROCEEDINGS OF ICUPC - 5TH INTERNATIONAL CONFER, pages 286-290 vol.1, XP002191059 1996, New York, NY, USA, IEEE, USA ISBN: 0-7803-3300-4	8-10
A	figures 2,3 page 287, left-hand column, line 5 -page 287, right-hand column, line 2 --- -/--	1

[X] Further documents are listed in the continuation of box C.

[ ] Patent family members are listed in annex.

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 February 2002	07/03/2002

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Scalia, A

Interna ıplication No
PCT/GB 01/05032

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	DR-JIUNN DENG ET AL: "A nonpreemptive priority-based access control scheme for broadband ad hoc wireless ATM local area networks" IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS, SEPT. 2000, IEEE, USA, vol. 18, no. 9, pages 1731-1739, XP002191060 ISSN: 0733-8716 figure 1 page 1732 -page 1733 -----	1,8-10